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THE EFFECTS OF MAGNETIC STORM PHASES ON F-LAYER IRREGULARITIES FROM AURORAL TO EQUATORIAL LATITUDES

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COMPARISON OF F-LAYER IRREGULARITIES DURING PERIODS OF HIGH AND LOW SOLAR FLUX

EQUATORIAL STUDIES

The review of equatorial data relative to F-layer irregularities continued during this period with an emphasis in this quarter on the results of a long series of optical measurements. The study uses the largest optical data base yet obtained of equatorial airglow depletions to describe such observational features of irregularity plume onset and development under different seasonal and geomagnetic conditions. We are most interested in the data showing the extreme altitudes/latitudes reached by such effects.

The wide angle imaging technique of emission of the 6300 Å line offers a unique capability to characterize the morphology of depleted flux tubes over regions spanning several million square kilometers. To date, all such studies have been conducted during relatively brief campaigns, ranging from a few days per airborne study to a few weeks for groundbased observations. To extend such observations over a far longer time span, an all-sky imaging system was put into operation at Cachoeira Paulista, Brazil (22.7° S, 45.0° W), in March 1987, as part of a bilateral collaborative project between the Center for Space Physics at Boston University and the Brazilian Institute for Space Research (INPE). The ONR contract is involved in the reduction and analysis of the data base. The equipment was supplied by Boston University. The low light level imaging system is very similar to that described by Mendillo and Baumgardner (1982). It was devoted exclusively to OI 630.0 nm airglow observations from March 1987 to July 1989, except during the low F-layer irregularity occurrence months of May and June, 1987, and June and July, 1988, when some test observations were made of Na D-line 589.3 nm and OI 557.7 nm emissions.

The altitudes over the equator when followed along the lines of force for images observed at Cachoeira Paulista are depicted in Figure 1. Airglow depletions attributed to a typical emission height of 300 km (Mendillo and Tyler (1983) can extend from the magnetic equator at the northern edge of the field of view to a latitude beyond the anomaly region (15°) at the southern edge of the field of view. Given the geomagnetic flux-tube nature of the plasma depletions that account for the reduced airglow, the airglow signatures at 300 km can be used to map the depletion back along the field to a height above the geomagnetic equator. This is referred to as the "apex height" of the depletion, and has been used to study the altitude/latitude extent of the instability

processes. Figure 1 gives an overlay pattern for CP images in which the apex altitudes are given in kilometers. Note that airglow depletions extending to the southern edge of the field of view relate to plasma depletions (bubbles, plumes) that extend to beyond 2500 km above the magnetic equator.

During the period March 1987 to October 1991, a nearly continuous series of simultaneous measurements of oxygen 630.0 nm emission were conducted using zenith viewing photometer and an all-sky imaging system at the INPE site in Cachoeira Paulista. Complementary data from ionosondes (at CP and on the equator) and VHF satellite radio beacon Faraday angle and amplitude scintillation measurements at CP were made during the period March 1987 to June 1989. This was a period of ascending solar cycle conditions when the monthly average 10.7 cm solar flux varied from 73.3 units to 247.2 units.

Virtually all ground based radar measurements of irregularity backscatter plumes have been made at either the Jicamarca Observatory in Peru or the ALTAIR facility on Kwajalein in the Marshall Islands. These instruments have generally been configured to obtain measurements near the peak and topside F-region, and thus the vast majority of observations reported in the literature show returns confined to altitudes below 900 km. Satellite observations have probed this region as well, with some results at similar and greater heights. Muldrew (1980) reported Alouette-I observations in the altitude range near 1000 km using the topside sounder technique of observing spread-F. The maximum altitude of in-situ irregularity detection appears to be documented in a paper by Burke et al. (1979) that reported on ISIS -I observations with a spherical electrostatic probe. Out of 300 orbits in the 20:00 to 03:00 LT period, only 21 showed large amplitude irregularities in the latitude range of ± 15 of the magnetic equator. At heights greater than 1500 km, only 6 ISIS orbits had large amplitude irregularities. All of the irregularities observed at heights over 1200 km were observed from midnight to 02:30 LT, suggesting that they were probably fossil bubbles that had "percolated up" from bottomside formation regions at earlier times. In the IES 1982 publication, Benson (1982) reported high altitudes using topside sounder conjugate point returns.

For optical data, Mendillo and Tyler (1983) have reported the highest altitudes noted for plumes during the pre-midnight formation times (1200 km) using the apex mapping technique applied to imaging observations made on Ascension Island.

The imaging results from Cachoeira Paulista show airglow depletions that extend to the southern edge of the field of view and, indeed, appear to continue to even more poleward regions. The apex grid shown in Figure 1 shows that such cases imply a depleted flux tube reaching to altitudes > 2500 km above the equator. The large data base from CP is ideal to document this characteristic in some detail. The vertical extent above the equator is related to the bubble rise speeds which, in turn, are generated by the instability process. If the latitude extent of such disturbed flux tubes reaches beyond equatorial anomaly regions, then perhaps some mid-latitude spread-F reports are actually related to equatorial processes.

Of interest to this study was the solar cycle influence on the apex height extents. The maximum altitudes reached during several nights during the relatively low solar flux month of January 1988 in comparison to sample nights during the higher solar flux month of January 1990. While similar maximum heights occur during each period, there are more nights with lower altitude maxima during a low solar flux year than during the same month of a solar maximum year.

Findings include:

(1) The observed seasonal variation of the airglow depletions shows a maximum in occurrence from November to January, with virtually no airglow depletions during magnetically quiet times during June to August.

(2) On about 40% of the nights on which airglow depletions occurred, both the initial formation sequence and their subsequent eastward motion were observed. On the remaining 60% of nights showing airglow depletions, only the latter convection phase of foscil depletions was observed.

(3) The formation phase was characterized by an initial lowering of intensities in the equatorward portion of the field of view (FOV), corresponding to the pre- reversal enhancement of vertical drifts near the magnetic equator. This was followed by airglow depletions protruding from equatorial regions to anomaly latitudes, and perhaps beyond.

(4) Using a geomagnetic field model, the airglow depletions can be mapped to their apex height about the geomagnetic equator. For a clear majority of cases examined over the full data base years, the apex heights were most often above 1500 km, and probably above 2500 km. This was true during both the low and high

solar flux years of the study

(5) During months when airglow depletions do not normally occur (April to September), geomagnetic disturbance induced vertical drifts appear to facilitate the initiation of airglow depletions, generally during the post-midnight hours.

The range of solar flux values available in this relatively long data set indicates that even during years of low solar flux, plumes develop to an extremely high altitude. This finding is of importance in developing the morphology of irregularity development. The maximum activity and effect on trans-ionospheric signals occurs at anomaly latitudes where fading at 4 GHz has reached peak to peak levels of 24 dB during years of high solar flux. During years of low solar flux, an extremely low level of scintillation activity has been reported during normally active months such as November and December for anomaly sites not too distant from the longitude of CP such as Ascension Island (Basu et al. , 1988). One proposed explanation has been that this is due to the lower altitudes of the developing plumes at low solar flux which do not "reach" the anomaly latitudes. However the two necessary conditions for a high level of scintillation in the anomaly region are high altitudes of the disturbance over the magnetic equator and high levels of electron density in the post-sunset time period at the anomaly site. Our data indicate that high altitudes are reached even during years of low solar flux. Then the low level of scintillation observed must be due in great part to the low electron density in the post-sunset time period in the anomaly region during years of low solar flux.

The extremely high altitudes frequently observed might explain the reporting of high scintillation values from ionospheric intersections considered to be polewards of the anomaly region.

COLLABORATIVE STUDIES

We have analyzed the data shared with us by Dr. Leonard Kersley of the University College of Aberystwyth, Wales and his group. Data from several periods of interest in the low sunspot years of 1985 and 1986 has been contoured. The data available for the study of contrasting low and high solar flux years includes that from the University College data set taken in Kiruna, Sweden as well as other data taken in Goose Bay, Labrador and equatorial sites. Evaluation of data sets has included new analysis as well as the utilization of older data, much of it at this date merely reduced.

PRESENTATIONS

The paper entitled The Longitudinal Occurrence of Equatorial F Layer Irregularities was presented at the Beacon Satellite Meeting held in Boston on the last week in June 1992. The presentation emphasized the evaluation of those components of the available data base relevant to the occurrence of equatorial plume irregularities. A paper on a similar subject but with emphasis on the physics and the relevance to systems such as GPS was presented at the AGARD Meeting on Radio Location Techniques held in the early part of June 1992.

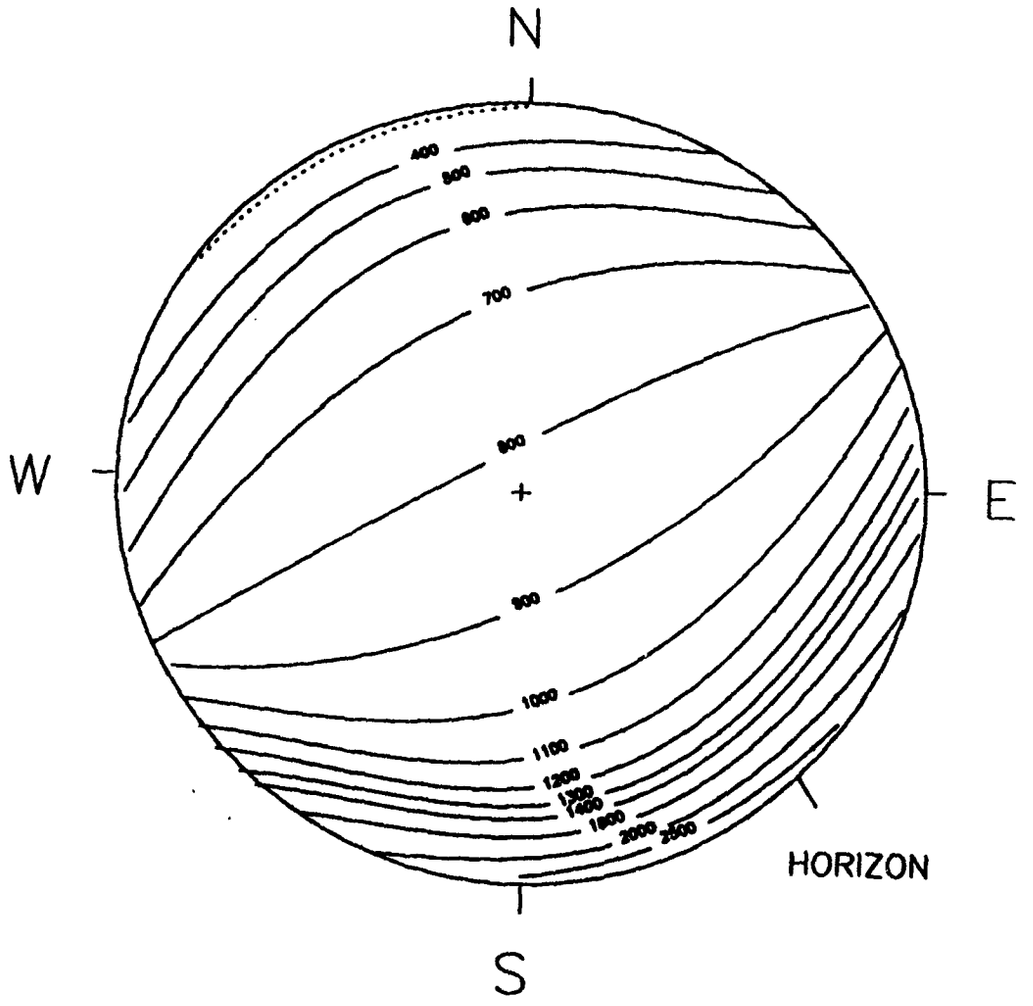

FIGURE 1

PROJECTED ALTITUDE OVER THE EQUATOR FOR 630nm

EMISSION AT 300km FOR 23°S, 45°W

HORIZON CIRCLE GIVES 90 DEGREE ZENITH DISTANCE

DOTTED LINE REPRESENTS THE MAGNETIC EQUATOR